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(54) OSCILLATORY GYRO AND TEMPERATURE DRIFT ADJUSTING METHOD THEREFOR

(57)Abstract:
PROBLEM TO BE SOLVED: To obtain an oscillatory gyro with a smaller temperature drift inexpensively with a simple circuitry.
SOLUTION: The oscillatory gyro 10 contains an oscillator 12 and an oscillation circuit 30 for exciting the oscillator 12. A terminal for detection of the oscillator 12 is connected to the ground through load resistances 26 and 28 while being connected to a differential circuit 32and an output signal of the differential circuit 32 is detected with a synchronous detection circuit 34. An output signal of the synchronous detection circuit 34 is smoothed by a smoothing circuit 36 and further amplified with an amplification circuit 38. The resistance values of the load resistance 26 and 28 are adjusted according to the degree of the inclination of the temperature drift of the oscillatory gyro 10 to minimize the degree of the inclination of the temperature drift.

CLAIMS

[Claim(s)]
[Claim 1]A vibrator which has the detection terminals for taking out an electric charge generated when Coriolis force is appliedLoad impedance for being connected to an oscillating circuit for vibrating said vibratorand said detection terminals of said vibratorand transforming said electric charge into voltageAnd a digital disposal circuit which processes an output signal from said detection terminals of said vibrator and to which a signal corresponding to the angular rate of rotation is made to output is includedA temperature drift adjustment method of a vibration gyroscope which minimizes said temperature drift tilting amount by adjusting said load impedance according to a temperature drift tilting amount which shows change of output voltage from said digital disposal circuit to a temperature change.

[Claim 2]A temperature drift adjustment method of the vibration gyroscope according to claim 1 with whichas for said vibratorsaid load impedance is connected to each of said detection terminals including said at least two detection terminalsand a relation of an impedance value of said at least two load impedance is adjusted.
[Claim 3]A vibration gyroscope to which a temperature drift was adjusted by a temperature drift adjustment method of the vibration gyroscope according to claim 1 or 2.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention]This invention about a vibration gyroscope and a temperature drift adjustment method for the sameThe system which performs behavior detection of a mobile by detecting the angular rate of rotation especiallyfor exampleOr it is related with the vibration gyroscope applied to vibration removal systemssuch as a shaking hand arrester which detect the angular rate of rotation by external vibration of the navigation system which detects the position of a mobile and performs suitable derivationor a shaking handand performs proper dampingetc.and its temperature drift adjustment method.
[0002]
[Description of the Prior Art]Drawing 10 is an illustration figure showing an example of the conventional vibration gyroscope. The vibration gyroscope 1 contains the vibrator 2. The vibrator 2 contains the vibration body 3 of the Shozo prismatic formfor example. The piezoelectric elements 4a4band 4c are formed in three sides of the vibration body 3respectively. An electrode is formed in both sides of this piezoelectric layer including the piezoelectric layer which these piezoelectric elements 4a4band 4c becomefor example from porcelain. And one electrode of the piezoelectric elements 4a4band 4c pastes the side of the vibration body 3.
[0003]The oscillating circuit 5 is connected between the piezoelectric elements 4a and 4b and the piezoelectric element 4c. And the output signal from the piezoelectric element 4c returns to the oscillating circuit 5and the driving signal acquired by phase correction being amplified and carried out here is given to the piezoelectric elements 4a and 4b. With this driving signalflexing vibration of the vibration body 3 is carried out to the direction which intersects perpendicularly with a piezoelectric element 4c forming face.
[0004]The two piezoelectric elements 4a and 4b are connected to a digital disposal circuit. A digital disposal circuit comprises the differential circuit 6the synchronous detection circuit 7the smoothing circuit 8the amplifying circuit 9etc. And the piezoelectric elements 4a and 4b are connected to the input edge of the differential circuit 6. The outgoing end of the differential circuit 6 is connected to the synchronous detection circuit 7. In the synchronous detection circuit 7the output signal of the differential circuit 6 is detected synchronizing with the signal of the oscillating circuit 5. The synchronous detection circuit 7 is connected to the smoothing circuit 8and the smoothing circuit 8 is further connected to the amplifying circuit 9.
[0005]In this vibration gyroscope 1the vibration body 3 carries out flexing vibration to the direction which intersects perpendicularly with a piezoelectric element 4c forming

face by the oscillating circuit 5. At this timesince the output signal of the piezoelectric elements 4a and 4b is the samefrom the differential circuit 6the signal of the piezoelectric elements 4a and 4b is not outputted. In this stateif the axis of the vibration body 3 is rotated as a centerthe vibrating direction of the vibration body 3 will change by Coriolis force. Therebybetween the piezoelectric element 4a and 4bthe difference of an output signal arises and a signal is outputted from the differential circuit 6. The output signal of the differential circuit 6 is detected in the synchronous detection circuit 7and after smoothness is carried out further in the smoothing circuit 8it is amplified in the amplifying circuit 9. Since the output signal of the differential circuit 6 supports change of the vibrating direction of the vibration body 3if the output signal of the amplifying circuit 9 is measuredit can detect the angular rate of rotation added to the vibrator 2.
[0006]In such a vibration gyroscope 1at the time of nonrotationthe vibrator 2 is formed so that the signal which serves as reference voltage near 25 ** may be outputtedbut there is a temperature drift in the output signal of the vibrator 2 or a digital disposal circuitand an output signal changes with ambient temperature. It is possible to consider it as circuitry which null voltage (drift component) does not generate as a method of suppressing such a temperature drift. The voltage of the self by which signal processing was carried out to the generated null voltage is subtracted and addedand there is the method of canceling a temperature drift as shown in JP7-91957A. Temperature characteristics are given to the gain of a digital disposal circuitthe temperature drift ingredient of a vibration gyroscope is canceled using the gain temperature characteristicsand there is a method of obtaining a desired temperature drift as shown in JP2000-171258A.
[0007]As the circuit shown in JP7-91957A is shown in drawing 11the signal outputted from the two piezoelectric elements 4a and 4b of the vibrator 2 is inputted into the differential amplifying circuit 6and the output signal of the differential amplifying circuit 6 is inputted into the two synchronous detection circuits 7a and 7b. Although the output signal of the differential amplifying circuit 6 is detected in one synchronous detection circuit 7a like the vibration gyroscope shown in drawing 10synchronizing with the signal with which about 90 degrees of phases differ from the synchronized signal in the synchronous detection circuit 7athe output signal of the differential amplifying circuit 6 is detected in the synchronous detection circuit 7b of another side. Thusfrom one synchronous detection circuit 7aa part for the amplitude difference of the drift components is outputtedand a part for the phase contrast of the drift components is outputted from the synchronous detection circuit 7b of another side. And although null voltage is canceled by taking the difference of these drift componentsthe temperature compensation circuit is provided so that these drift components may be mostly in agreement.
[0008]As the vibration gyroscope shown in JP2000-171258A is shown in drawing 12 in a circuit as shown in drawing 10gain temperature-characteristics setting out is made so that it may have a temperature drift contrary to the temperature drift of a vibratorand offset control is made. As shown in drawing 13the signal which has almost fixed offset voltage is outputted irrespective of change of temperature by it. The output at the time of nonrotation can be easily doubled with the value of requestssuch as reference voltageor Vdd/2by using the 2nd offset adjustment circuit.
[0009]
[Problem(s) to be Solved by the Invention]Howeverwhen it is going to make it a circuit

which the null voltage of a vibrator does not generatesince the generation factor of null voltage is complicatedthe circuitry for canceling it will also become very complicated. There are many circuits added in a vibration gyroscope as shown in drawing 11and since a temperature drift ingredient occurs also from these circuitsit is difficult to oppress the temperature drift ingredient of the whole vibration gyroscope. In the case of the vibration gyroscope which gave temperature characteristics to the gain of the digital disposal circuitcircuitry is comparatively easybut. after making offset voltage into about 1 lawin order to shift offset voltage so that a temperature drift may be made smalloffset control must be performed againand two offset control circuit parts are needed. Thereforean adjusting process becomes complicated and is not so preferred.
[0010]Sothe main purpose of this invention is easy circuitryand is providing the small vibration gyroscope of a temperature drift cheaply. The purpose of this invention is to provide the temperature drift adjustment method which can obtain the above vibration gyroscopes.
[0011]
[Means for Solving the Problem]A vibrator which has the detection terminals for taking out an electric charge generated when this invention requires Coriolis forceAn oscillating circuit for vibrating a vibratorand load impedance for being connected to detection terminals of a vibrator and transforming an electric charge into voltageA digital disposal circuit which processes an output signal from detection terminals of a vibrator and to which a signal corresponding to the angular rate of rotation is made to output is includedIt is a temperature drift adjustment method of a vibration gyroscope which minimizes a temperature drift tilting amount by adjusting load impedance according to a temperature drift tilting amount which shows change of output voltage from a digital disposal circuit to a temperature change. In a temperature drift adjustment method of such a vibration gyroscopeincluding at least two detection terminalsload impedance is connected to each of detection terminalsandas for a vibratora relation of an impedance value of at least two load impedance is adjusted. This invention is the vibration gyroscope to which a temperature drift was adjusted by a temperature drift adjustment method of an above-mentioned vibration gyroscope.
[0012]When Coriolis force worksa temperature drift occurs with a value of element impedance of a vibrator which an electric charge generates. At this timea temperature drift can be adjusted by adjusting a value of load impedance connected to detection terminals of a vibrator. When there are two detection terminals in a vibratora temperature drift can be adjusted by connecting load impedance to these two detection terminalsand adjusting a relation of such two load impedance. If such a method is adopteda temperature drift can be adjusted in an easy circuit and a cheap vibration gyroscope can be obtained.
[0013]The above-mentioned purpose of this inventionthe other purposesthe featureand an advantage will become still clearer from detailed explanation of the following embodiments of the invention given with reference to drawings.
[0014]
[Embodiment of the Invention]Drawing 1 is an illustration figure showing an example of the vibration gyroscope of this invention. The vibration gyroscope 10 contains the vibrator 12. As the vibrator 12as shownfor example in drawing 2some are bimorph type. This vibrator 12 contains the vibration body 18 which laminated the two tabular piezo

electric crystals 14 and 16. As shown in the arrow of drawing 2polarization of the piezo electric crystals 14 and 16 of each other is carried out for reverse. On the piezo electric crystal 14the electrodes 20a and 20b divided into two in the cross direction are formedand it is used as a terminal for detection for outputting the signal corresponding to Coriolis force. The whole surface on the piezo electric crystal 16the electrode 22 is formed and it is used as a terminal for excitation for carrying out flexing vibration of the vibration body 18.

[0015]As shown in drawing 3the vibrator 12 using the vibration body 24 of the Shozo prismatic form may be used. This vibration body 24 is formedfor example with materials which generally produce a mechanical vibrationsuch as an elinvaran iron nickel alloyquartzglasscrystaland ceramics.

[0016]The piezoelectric elements 26a26band 26c are formed in three sides of the vibration body 24respectively. An electrode is formed in both sides of this piezoelectric layer including the piezoelectric layer which these piezoelectric elements 26a26band 26c becomefor example from porcelain. And one electrode of the piezoelectric elements 26a26band 26c pastes the side of the vibration body 24. The two piezoelectric elements 26a and 26b are used as a terminal for detection for outputting the signal corresponding to Coriolis forceand other piezoelectric elements 26c are used as a terminal for excitation for carrying out flexing vibration of the vibration body 24.

[0017]The terminal for detection of the vibrator 12 is connected to a ground via the load resistance 26 and 28 as load impedancerespectively. In order that such load resistance 26 and 28 may transform into voltage the electric charge generated by vibration of the vibrator 12it is usedbut since it is used also as an object for temperature drift adjustmenta variable resistor etc. are used as the load resistance 26 and 28.

[0018]The terminal for detection of the vibrator 12 is connected to the input edge of the oscillating circuit 30. After the output signal from two terminals for detection of the vibrator 12 is added and phase correction of the oscillating circuit 30 is carried out including an adder circuitan amplifying circuitand a phase-shifting circuitit is amplified and a driving signal is formed. This driving signal is given to the terminal for excitation of the vibrator 12and the vibrator 12 vibrates. In this caseby the vibrator 12 shown in drawing 2the vibration body 18 carries out flexing vibration to the direction which intersects perpendicularly with the electrode 22 for excitationand the vibration body 24 carries out flexing vibration to the direction which intersects perpendicularly with an electrode 26c forming face by the vibrator 12 shown in drawing 3.

[0019]The terminal for detection of the vibrator 12 is connected to a digital disposal circuit. In a digital disposal circuitthe terminal for detection of the vibrator 12 is connected to the input edge of the differential circuit 32 including the differential circuit 32the synchronous detection circuit 34the smoothing circuit 36the amplifying circuit 38etc. The outgoing end of the differential circuit 32 is connected to the synchronous detection circuit 34. In the synchronous detection circuit 34the output signal of the differential circuit 32 is detected synchronizing with the signal of the oscillating circuit 30. The synchronous detection circuit 34 is connected to the smoothing circuit 36and the smoothing circuit 36 is connected to the amplifying circuit 38.

[0020]Vibration is excited by the oscillating circuit 30 in such a vibration gyroscope 10. For exampleflexing vibration is excited in the vibrator 12 as shown in drawing 2 or drawing 3. Since the same signal is outputted from two terminals for detection at this

timethe signal of the terminal for detection is not outputted from the differential circuit 32. In this stateif the angular rate of rotation is added to the vibrator 12the vibrational state of the vibrator 12 will changea difference will arise to the signal outputted from two terminals for detectionand a signal will be outputted by Coriolis force from the differential circuit 32. The output signal of the differential circuit 32 is detected in the synchronous detection circuit 34and after smoothness is carried out further in the smoothing circuit 36it is amplified in the amplifying circuit 38. Since the output signal of the differential circuit 32 supports change of the vibrational state of the vibrator 12if the output signal of the amplifying circuit 38 is measuredit can detect the angular rate of rotation added to the vibrator 12.

[0021]In such a vibration gyroscope 10it is formed so that the signal which serves as reference voltage near 25 ** may be outputted at the time of nonrotationbut there is a temperature drift in the output signal from the vibrator 12 or a digital disposal circuitand as shown in drawing 4an output signal changes with ambient temperature. Let change (deltaV) of the output voltage from the digital disposal circuit to a temperature change (deltaT) be a temperature drift tilting amount (deltaV/deltaT) in drawing 4. If the resistance of the load resistance 26 and 28 is made into R_L and $R_R$respectively when the resonance characteristic of two elements of the vibrator 12 has gatheredAs shown in drawing 5when a temperature drift tilting amount is set to 0 at the time of $R_L=R_R$ and the difference between R_L and R_R becomes largea temperature drift tilting amount also has the relation of becoming large.

[0022]That iswhen the resonance characteristic of the element of the vibrator 12 is almost the sameas shown in drawing 6both impedance Z_L and Z_R also become almost the same. At this timeboth change is also the same as whenas for the amplitude and the phase of voltage V_L outputted from two elements called for by the division ratio of Z and Rand V_Ra set and temperature change mostly by making resistance R_L of the load resistance 26 and 28and R_R into the same value. In this casea temperature drift is hardly generated but a temperature drift tilting amount is set to about 0.

[0023]Howeverif the resistance of the load resistance 26 and 28 is made into $R_L=R_R$ when both impedance shiftsfor example like $Z_L>Z_R$ with manufacture dispersion etc.The amplitude of the detection voltage obtained by the division ratio of Z and R becomes $V_L<V_R$phase contrast is also producedand the relation between a load resistance value and element impedance shifts. Thereforewhen ambient air temperature changesboth amplitude and a phase changethe detection phase to a synchronous detection signal changesand it appears as a temperature drift.

[0024]Thenby making a load resistance value into $R_L>R_R$when a difference arises in both impedancefor example like $Z_L>Z_R$ in this vibration gyroscope 10Amplitude of the detection voltage obtained by a division ratio can be made into V_L**$V_R$and can also arrange a phase mostly. Thereforeas shown in the sample A and the sample B of drawing 7at the time of $Z_L>Z_R$. A temperature drift tilting amount can be set to 0 by considering it as $R_L>R_R$and when it is $Z_L<Z_R$a temperature drift tilting amount can be set to 0 by considering it as $R_L<R_R$.

[0025]Since the equivalent circuit of impedance Z_L of the element of the vibrator 12 and Z_R comprises resistancea capacitorand an inductor as shown in drawing 8a load resistance value cannot only be changed and the inclination of a temperature drift cannot be made into the minimum only by arranging amplitude and a phase. Thena temperature drift

tilting amount can serve as the minimum by computing a tilting amount by measuring the temperature drift in $R_L=R_R$following an experimental formulaand performing final adjustment of R_L and R_R. Herean experimental formula shows the expression of relations of the temperature drift and load resistance value which are shown in drawing 5 or drawing 7.
[0026]In order to perform such adjustmentthe resistance of the load resistance 26 and 28 is adjustedbut a temperature drift tilting amount can be adjusted by adjusting that trimming quantity by using trimming resistance as a variable resistor used as the load resistance 26 and 28 in this case.
[0027]Although the temperature drift of a vibration gyroscope is not adjustedin order to adjust null voltagethe example which connected the variable resistor to one side of the detection terminals of a vibrator is shown in JP8-189834A. In this vibration gyroscope 1as shown in drawing 14one side of two detection terminals formed in the side of the cylindrical vibration body 3 is connected to a ground via a variable resistorand another side of two detection terminals is connected to a ground via fixed resistance.
[0028]In this vibration gyroscope 1since the resistance connected to the detection terminals of the vibrator 2 is not used as input resistance to a differential amplifying circuiteven if it adjusts null voltage by adjusting a variable resistorthe detection sensitivity of a digital disposal circuit can be kept constant. Howeverin such a vibration gyroscope 1when forming a variable resistor by trimming resistance etc.resistance cannot be fluctuated but it can adjust only to one way. Thereforeadjustment of null voltage also turns into adjustment of only one way. Thereforeif manufacture dispersion of a vibratoretc. are taken into considerationtrimming resistance is formed so that it may become the resistance from which null voltage shifts to one side greatly beforehandand it is necessary to adjust null voltage by performing trimming. Thereforeit is necessary to adjust trimming resistance about almost all vibration gyroscopes.
[0029]To itin the vibration gyroscope 10 of this invention. Since the temperature drift is adjusted by adjusting the relation of the load resistance 26 and 28 connected to two detection terminals of the vibrator 12A temperature drift can be adjusted to both directions by adjusting either of the load resistance 26 and 28 like the sample A shown in drawing 7and the sample B. Thereforeit is not necessary to shift the resistance of the load resistance 26 and 28 greatly beforehandand the temperature drift of the vibration gyroscope 10 can be suppressed by easy adjustment.
[0030]Thussince adjustment of the temperature drift of the vibration gyroscope 10 can be performed by easy adjustmentthe load resistance 26 and 28 is constituted from a series circuit of fixed resistance and a variable resistorand it may enable it to tune it finelyas shown in drawing 9. In this caseeven if it adjusts a variable resistoras the whole load resistance 26 and 28resistance cannot change a lotbut highly precise adjustment can be performed.
[0031]Although load resistance was used as load impedance in the vibration gyroscope 10 shown in drawing 1 or drawing 9as long as it is an element which can transform into voltage the electric charge generated in the vibrator 12a capacitor or an inductor may be sufficient. If a temperature drift occurs even if it is things other than structure as shown in drawing 2 or drawing 3 as the vibrator 12the art of this invention is applicable.
[0032]
[Effect of the Invention]According to this inventionthe circuit of easy composition can be

usedit is cheap andmoreoverthe small vibration gyroscope of a temperature drift can be obtained.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1]It is an illustration figure showing an example of the vibration gyroscope of this invention.
[Drawing 2]It is a perspective view showing an example of a vibrator used for the vibration gyroscope shown in drawing 1.
[Drawing 3]It is a perspective view showing other examples of the vibrator used for the vibration gyroscope shown in drawing 1.
[Drawing 4]It is a graph for explaining the temperature drift tilting amount of a vibration gyroscope.
[Drawing 5]When two element impedance of a vibrator is equalit is a graph which shows a temperature drift tilting amount when the resistance of load resistance is made equal.
[Drawing 6]It is a representative circuit schematic showing the relation between the element impedance of a vibratorand load resistance.
[Drawing 7]When two element impedance of a vibrator has a differenceit is a graph which shows the temperature drift tilting amount at the time of providing a difference in the resistance of load resistance.
[Drawing 8]It is a representative circuit schematic of the element impedance of a vibrator.
[Drawing 9]It is an illustration figure showing other examples of the vibration gyroscope of this invention.
[Drawing 10]It is an illustration figure showing an example of the conventional vibration gyroscope.
[Drawing 11]It is an illustration figure showing other examples of the conventional vibration gyroscope.
[Drawing 12]In the vibration gyroscope shown in drawing 10it is a graph which shows the vibrator temperature drift and digital-disposal-circuit temperature characteristics at the time of giving temperature characteristics to the gain of a digital disposal circuit.
[Drawing 13]It is a graph which shows the output voltage obtained from the vibration gyroscope which has the characteristic shown in drawing 12.
[Drawing 14]It is an illustration figure showing the conventional vibration gyroscope for comparing with the vibration gyroscope of this invention.
[Description of Notations]
10 Vibration gyroscope
12 Vibrator
26 and 28 Load resistance
30 Oscillating circuit
32 Differential circuit
34 Synchronous detection circuit
36 Smoothing circuit
38 Amplifying circuit